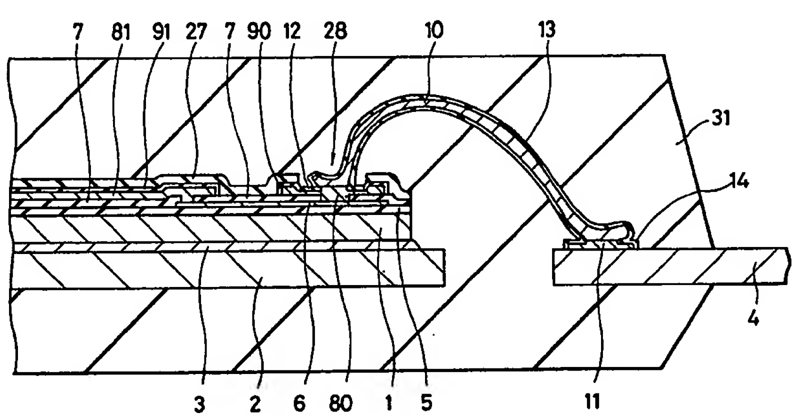
(12) UK Patent Application (19) GB (11) 2 105 107 A

(21) Application No 8221354
(22) Date of filing 23 Jul 1982
(30) Priority data
(31) 56/115080
56/115081
56/115082
56/122994
(32) 24 Jul 1981
24 Jul 1981
24 Jul 1981
7 Aug 1981
(33) Japan (JP)
(43) Application published
16 Mar 1983
(51) INT CL[3]
H01L 21/473 21/44
(52) Domestic classification
H1K 1AA9 3S2 5B1 5B2
5B9 5C3A 5C3E JAX
(56) Documents cited
None
(58) Field of search
H1K
(71) Applicants
Hitachi Ltd.,
(Japan),
5-1 Marunouchi 1-chome,
Chiyoda-ku,
Tokyo,
Japan.
(72) Inventors
Tamotsu Usami
(74) Agents
Mewburn Ellis and Co.,
2/3 Cursitor Street,
London,
EC4A 1BQ.

(54) **Semiconductor device and fabrication method thereof**

(57) A semiconductor device, in which, in order to prevent both a wiring layer (81) including a bonding pad (6, 80) of aluminum and a bonding wire (10) from corroding, the aluminum material has formed on its surface an aluminum oxide film (90, 12, 13). In the semiconductor device disclosed, a first aluminum oxide film (90, 91) is formed on the surface of an upper aluminum wiring (80, 81) underlying a final passivation film (27), and a second aluminum oxide film (12, 13) is formed on both an exposed surface of a bonding pad (80) and the surface of a bonding wire (10). In order to ensure the high quality of the second aluminum oxide film (12, 13), the materials of the bonding pad and the bonding wire are made to have an identical ionization tendency, or all leads are short-circuited when the oxidization for the second oxide film is conducted. In order that electrical connection to the bonding pad may not be broken during the oxidization of the second oxide film, moreover, the bonding pad is made to have a stacked construction of two aluminum layers (6, 80).

FIG. 1



GB 2 105 107 A

SPECIFICATION

Semiconductor device and fabrication method thereof

The present invention relates to semiconductor devices and a fabrication method thereof, and more particularly to countermeasures against humidity faults.

Humidity faults caused by moisture are one of the major fault modes of semiconductor devices. Such a humidity fault is caused by the corrosion of aluminum ($A\ell$) in the semiconductor device. As is well known in the art, aluminum is a very widely used material in semiconductor devices because it is easily worked and inexpensive. Specifically, aluminum is used in a semiconductor chip for wiring layers, bonding pads and bonding wires for electrically connecting the bonding pads to lead posts. The aluminum thus used is liable to corrode when it contacts with moisture which has penetrated into the package. This corrosion is more liable to occur especially if there are ions such as NA^+ or $C\ell^-$ or stains in the vicinity of the aluminum or if a voltage is biased upon an aluminum layer.

There have been proposed in the art a variety of methods for preventing such humidity faults. In one of the known methods, noting that an aluminum oxide ($A\ell_2O_3$) has an excellent corrosion resistance, the surface of aluminum is oxidized to form an aluminum oxide film so that it may thereby be prevented from corroding. In Japanese Patent Laid-Open Publication No. 52 - 117551, for example, there is a disclosure that a bonding wire and a bonding pad made of aluminum have their surfaces oxidized to form oxide films. In Japanese Patent Laid-Open Publication No. 53-9470, on the other hand, there is found a disclosure that an aluminum wiring layer in a chip has its surface oxidised to form an oxide film.

No matter how excellent the corrosion resistance of the aluminum oxide film is, however, there exists no practical product in which a bonding pad of aluminum and a bonding wire for connection with the former have their surfaces oxidised to form oxide films. In order to prevent humidity faults in practice, reliance is placed upon making the package gas tight or on improvements in the resin material. The failure to use aluminum oxide films on the surface of aluminum with a view to preventing the humidity fault in the prior art as thus far described is because the method of the prior art has failed to form the aluminum oxide film in a satisfactory manner. More specifically, the prior art method has failed to efficiently form an aluminum oxide film having a uniform thickness and good corrosion resistance. This cause has not been made clear and raises a serious difficulty.

Moreover, the construction of the prior art has a problem that the wiring is frequently broken at the bonding pad portion so that it does not make a good connection. This is because, when the exposed surface of the bonding pad is oxidized to form an aluminum oxide film, the oxidized region is not limited merely to the surface portion but reaches deep into the aluminum layer thereby deteriorating the connection between the aluminum layer of the bonding pad and the aluminum layer of the wiring.

The construction of the prior art has another problem that the corrosion resistance is not improved to a sufficient extent. This is because aluminum wiring underlying a final passivation film is caused to corrode by moisture which penetrates through cracks formed in the final passivation film.

According to one aspect of the present invention, the material making the bonding pad and the material making the bonding wire are aluminum materials containing additives and having an identical ionization tendency.

According to another aspect of the present invention, moreover, when that surface portion of the bonding pad of aluminum, which is not covered with a final passivation film, and the surface of the bonding wire of aluminum are to be oxidized to form aluminum oxide films, these oxidizations are conducted by short-circuiting the leads which are connected with the respective bonding wires.

According to still another aspect of the present invention, furthermore, the bonding pad is constructed of two upper and lower aluminum layers, of which the lower aluminum layer forms the wiring layer to the bonding pad whereas the upper aluminum layer forms a bonding portion, and the bonding wire of aluminum is bonded to the stacked portion in which those two aluminum layers are connected.

According to a further aspect of the present invention, furthermore, there are provided two aluminum oxide films, one of which is formed by oxidization on the surface of the aluminum layer underlying the final passivation film and the other of which is formed by oxidization on both such a surface portion of the bonding pad of aluminum as is not covered with the final passivation film and the surface of the bonding wire of aluminum.

An embodiment of the present invention will be described in the following with reference to the accompanying drawings, wherein:

Figure 1 is a sectional view showing a portion of a finished product of a semiconductor device according to the present invention;

Figure 2 is a top plan view schematically showing a bonding pad of the semiconductor device of Figure 1 in an enlarged scale; and

Figures 3A to *3F*, *Figure 4* and *Figure 5* are views showing a fabrication process of the semiconductor device of Figure 1.

Figure 1 is a sectional view schematically showing an embodiment of the present invention. This embodiment provides a construction in which the present invention is applied to a resin mold type semiconductor device. The whole of this semiconductor device is encapsulated in a molded resin 31, except a portion of a lead 4 which provides an external terminal thereof. Incidentally, the left-hand side sectional view of the semiconductor device is omitted from Figure 1.

Reference numeral 1 indicates a silicon semiconductor substrate. In this substrate 1, there is formed such a semiconductor element as will be shown in Figure 3A. Over the substrate 1, more specifically, there is formed a first aluminum layer 6

which is located on a first interlayer insulating film 5 made of SiO_2. That aluminum layer 6 forms both a part of a bonding pad 28 of a stacked structure according to the present invention and a lower wiring layer for connecting the bonding pad 28 and another portion (i.e., an aluminum layer 81). On that aluminum layer 6, there is formed a second interlayer insulating film 7 of SiO_2, on which second aluminum layers 80 and 81 are formed. These aluminum layers are made of aluminum materials which contain 1% of silicon (Si) and 1% of copper (Cu).

Those aluminum layers construct the upper wiring layer 81 and the bonding portion 80 which forms a part of the bonding pad 28 having the stacked structure according to the present invention. Thanks to the stacked structure of the bonding pad 28 composed of the aforementioned aluminum layer 6 and the bonding portion 80, it is possible to prevent the break which might otherwise take place at the portion of the bonding pad during the later oxidization of aluminum for forming an aluminum oxide film 12.

The additive silicon is added to prevent the aluminum from musutally diffusing or reacting by a heat treatment at a portion, in which it contacts with a semiconductor region forming a shallow junction, thereby to break the junction. On the other hand, the copper is added to prevent an aluminum wiring from being broken by the electromigration phenomena. Numerals 90 and 91 indicate aluminum oxide films which are formed on the top and side surfaces of the bonding portion 80 and the aluminum wiring layer 81, respectively (i.e. on the surfaces which are not in contact with the interlayer insulating film 5). They are prepared by oxidizing the surfaces of the bonding portion 80 and the aluminum wiring layer 81, respectively. The aluminum oxide films thus formed are made mainly of $A\ell_2O_3$. The aluminum oxide films 90 and 91 are disposed below a final passivation film described below so that they act as protecting films to prevent the aluminum layer 81 from corroding and are effective to prevent corrosion especially if a crack or the like forms in the final passivation film.

The whole surface of the chip except the bonding pad 28 is covered with the final passivation film 27 which is made of a phospho-silicate glass film (i.e., a PSG film).

The structure thus far described is die-bonded to a tab lead 2 by means of a gold-silicon eutectic 3. That tab lead 2 forms a part of the lead frame and is made of a 42 alloy (or phosphor bronze).

On the other hand, the outer connecting lead 4 forming a part of the lead frame and made of 42 alloy (or phosphor bronze) has its one end formed with an aluminum vapor-desposited film 11 for the wire bonding purpose and its other end protruding to the outside of the resin 31.

Reference numeral 10 indicates a bonding wire which is used to connect the outer connecting lead 4 and the bonding pad 28 and which has its one end bonded to the bonding pad 28 and its other end bonded to the aluminum vapor-deposited film 11 overlying the outer connecting lead 4. That bonding wire is made of an aluminum material which contains 1% of silicon and 1% of copper. That is to say, according to the present invention, a material having an identical ionization tendency to that of the bonding portion 80 is used to make the bonding wire.

The Inventor has investigated the causes for the failure to efficiently form a highly corrosion-resistive aluminum oxide film having a uniform thickness and has revealed that the causes come from the cell reaction which takes place locally in the vicinity of such a portion as is oxidized when the surface of an aluminum material is oxidized to form an aluminum oxide film. It has also been revealed as a result of his investigation that one of the causes for establishing that local cell reaction comes from the difference between the material of the aluminum wiring layer constructing the bonding pad and the material of the aluminum wire.

Usually, silicon and copper are added to the aluminum wiring layer, whereas silicon and magnesium are added to the aluminum wire. In accordance with the differences in the materials and quantities of various additives having different ionization tendencies and added to the aluminum except the silicon, there is established a difference in the ionization tendency between the aluminum wiring layer and the aluminum wire.

To the aluminum wiring layer, for example, there is added the copper (Cu) for preventing the electromigration thereof. To the aluminum wire, on the other hand, there is added the magnesium (Mg) for making the hardness (especially during the bonding step) excellent. In this case, according to the experiments conducted by the Inventor, the oxidization rate of the aluminum wiring layer is substantially equal to that of pure aluminum, whereas the oxidization rate of the aluminum wire is far higher than that of the pure aluminum so that a thicker aluminum oxide film than the portion of the wiring layer is formed. This is found to be caused partly by the fact that a local cell is equivalently constructed by moisture and the two substances having different ionization tendencies and partly by the fact that the ionization tendencies of the aluminum and the additives are expressed by inequalities Mg > Ap > Cu. Specifically, the reaction between the moisture and the aluminum is promoted by the catalytic action of the magnesium having a higher ionization tendency than the aluminum so that a stable aluminum oxide is formed. Since the copper has a lower ionization tendency than the aluminum, on the contrary, the catalytic action described in the above is not established so that the oxidization rate of the aluminum becomes substantially the same as that of pure aluminum. Moreover, this difference in the oxidization rates is further enlarged as a result that the movement of electrons during the oxidization is restricted by the afformentioned local cell reaction.

One aspect of the present invention is based on the aforementioned investigations conducted by the Inventor. In the device being described, by making the aluminum wiring layer forming the bonding pad and the aluminum wire of materials having an identical ionization tendency, it is made possible to

prevent the occurrence of the local cell reaction which might otherwise be caused by the difference between the ionization tendencies of the aluminum wiring layer and the aluminum wire. By this prevention, the growing rates of the oxide films to be formed on the surfaces of the two can be made equal so that a uniform thickness can be attained. Moreover, since the oxidizations proceed uniformly at an equal rate all over the surfaces, aluminum oxide films having an excellent quality can be obtained. Furthermore, since a uniform thickness can be attained, in contrast to the prior art, the disadvantage that one of the oxide films has a larger thickness than that required so as to retain a necessary thickness is eliminated so that the formation of the oxide films can be efficiently effected.

The resultant effects thus far described are not limited to the case where the additive to the aluminum region is copper. More specifically, if a substance having an ionization tendency is used as an additive in either the bonding pad of aluminum or the bonding wire, the aforementioned effects according to the present invention can be enjoyed, if the same substance is added to the other, no matter what the additive is. In this instance, it is desired that the quantity of addition be at a ratio as equal as possible.

Incidentally, the hardness of the aluminum wire, which may be important in the bonding step, can be made suitable for the bonding purpose by adding the silicon and copper thereto.

Aluminum oxide films 12 and 13 are so formed as to cover the surfaces of the bonding portion 80 and the bonding wire 10 of the structure thus wire-bonded. Those two aluminum oxide films are formed by oxidizing the surfaces of the aluminum regions they cover and are made mainly of $A\ell_2O_3$. The two aluminum oxide films are so formed as to merge into an integral film. By forming the aluminum oxide films in the manner thus far described, the bonding wire 10 and the bonding portion 80 can be prevented from corroding thereby to have their humidity resistances remarkably improved. On the other hand, reference numerals 12, 13 and 14 indicate aluminum oxide films which merge into an integral layer and which are formed by simultaneously oxidizing the bonding portion 80, the bonding wire 10 and the aluminum vapor-deposited film 11, respectively.

In the present embodiment, there are formed both the aluminum oxide films 90 and 91, which cover the upper aluminum wiring layer underlying the final passivation film, and the aluminum oxide films 12 and 13 (and 14) which cover the aluminum wire and the bonding pad (and the aluminum vapor-deposited film). Moreover, the aluminum oxide films 12 and 90 are so formed as to merge into an integral film at the bonding portion 80.

With the present embodiment, therefore, the aluminum can be prevented from corroding by the coactions between the moisture, which penetrates from the outside of the IC either into the resin 31 itself or through the clearance between the resin 31 and the lead 4, and the ions of impurities contained. By the aluminum oxide films 12, 13 and 14, moreover, the bonding portion 80, the aluminum wire 10 and the aluminum vapor-deposited film 11 covered thereby can be prevented from corroding. Still moreover, since those aluminum oxide films merge, the corrosion will not proceed from the boundaries between the aforementioned three regions. On the other hand, even if a crack is formed in the final passivation film 27 by mold stress, which is caused by the bridging reactions of the region or by the shrinking stress due to the difference in the coefficients of thermal expansion of the respective regions, or other various mechanical stresses, corrosion of the upper aluminum wiring layer 81 is prevented by the aluminum oxide film 91. Furthermore, since the aluminum oxide films 12 and 90 merge into each other, the corrosion can be prevented from proceeding through the clearance between the end portion of the final passivation film 27 and the bonding portion 80.

Figure 2 is a schematic top plan view showing the oxidized bonding pad 28 of Figure 1. In the same Figure, the aluminum oxide film 12 or 13 is shown partially removed for convenience, to show the underlying aluminum region 80 or 10.

The first aluminum layer 6, forming part of the stacked structure of the bonding pad 28, as indicated by single-dotted lines, and the bonding portion 80, which is the second aluminum layer, as indicated by double-dotted lines, contact directly with each other through a contact hole 32 which is opened, as indicated by broken lines, in the interlayer insulating film (although not shown) formed inbetween. That is to say, in the contact hole 32, the bonding pad 28 is constructed of a stacked structure in which the first and second aluminum layers 6 and 80 are in direct contact. The wire bonding step is so effected as to cover the portion of that stacked structure, i.e., the contact hole 32. Specifically, the wire bonding step is effected such that the bonding region in which the aluminum wire 10 and the bonding portion 80 contact completely covers the contact hole 32, as indicated by the broken lines 33 in the Figure.

Thus, it is possible to completely prevent such a break at the bonding pad as might otherwise be caused when the aluminum oxide film 12 is formed by oxidizing the bonding portion 80. The aluminum oxide film 12 is formed on regions other than the portion covered with the PSG film 27 and the bonding region 33 (which is covered with the aluminum wire 10), and not on the portion overlying the contact hole 32. As a result, even if the bonding portion 80 is wholly oxidized from the surface to the bottom thereby to allow the aluminum oxide film 12 to allow the underlying interlayer insulating film 7, the electric connection is maintained at an excellent level by the stacked structure at the contact hole 32. The bonding portion in the bonding region 33, which is covered with the aluminum wire 10, is not oxidized because it is not exposed to the moisture in an oxidizing atmosphere. As a result, the connection between the bonding portion 80 and the underlying aluminum layer 6 through the contact hole 32 can be maintained at an excellent level.

Figures 3A to 3F, Figure 4 and Figure 5 show a fabrication process of a semiconductor device of the

present invention.

On the P-type silicon semiconductor substrate 1, there is formed by the well-known process a semiconductor element which is shown in Figure 3A, for example. This semiconductor element is an NPN type bipolar transistor which has its collector region constructed of an N^+-type buried layer 15 and N^--type epitaxial layer 17, its base region constructed of a P-type region 19 and its emitter region constructed of an N^+-type region 20. In order to isolate that bipolar transistor from another semiconductor element, there are formed both a field oxide film 18, which is made of SiO_2, and a P^+-type channel stopper 16 which underlies the film 18. The P^+-type channel stopper 16 and N^+-type buried layer 15 are formed by ion implantation or the like before the formation of the epitaxial layer 17. On the other hand, the field oxide film 18 is formed by locally oxidizing the epitaxial layer 17.

After the semiconductor element thus far described has been formed, the substrate has its whole surface covered by the SiO_2 film 5 as the first interlayer insulating film by CVD (i.e., Chemical Vapor Deposition). Then, contact holes 23, 22 and 21 are opened to correspond to the collector, base and emitter regions, respectively.

Next, as shown in Figure 3B, a first wiring layer is formed. The SiO_2 film 5 has its whole surface covered by a first aluminum layer having a thickness of 2 μm by vacuum evaporation. Moreover, that aluminum layer is patterned to have a desired shape thereby to form the aluminum layer 6 which forms a part of the bonding pad 28 of the stacked structure and which provides a connecting wiring between the bonding pad 28 and another region in the chip. Simultaneously with this, moreover, there are formed aluminum wiring layers, 24, 25 and 26 for connecting the respective semiconductor regions.

As shown in Figure 3C, a second wiring layer and the bonding portion 80 of the bonding pad 28 are formed. The SiO_2 film 7 is formed as the second interlayer insulating film all over the surface by the CVD. Then, the contact hole for connecting the wiring layers and the contact hole 32 for constructing the bonding pad 28 into the stacked construction are opened. After that, the whole surface is covered by vacuum evaporation with the aluminum layer having a thickness of 4 μm and containing 1% of silicon and 1% of copper. This is then patterned into a desired shape to form the bonding portion 80 of the bonding pad 28 of the stacked structure. Simultaneously with this, the second wiring layer 81 is formed.

Next, as shown in Figure 3D, a first aluminum oxidization is conducted to form the aluminum oxide films 90 and 91. By leaving the wafer as a whole in the atmosphere at a temperature of 120°C and under a vapor pressure of 2 atms for ten minutes, the exposed surfaces of the patterned aluminum wiring layer 81 and the bonding portion 80 are oxidized. By these oxidations, the aluminum oxide films 90 and 91 are formed. These aluminum oxide films are made mainly of $A\ell_2O_3$. The aluminum oxide films are disposed below a final passivation film to be formed later and act as protecting films to prevent the aluminum layers 80 and 81 from corroding so that they are effective in the corrosion prevention especially in case a crack is formed in the final passivation film.

Next, as shown in Figure 3E, the PSG film 27 is so formed as the final passivation film all over the surface of the wafer by CVD to a thickness of 8000 Å. Moreover, both the aluminum oxide film 90 and the PSG film 27 on the bonding portion 80 are removed by a dry etching process such as the plasma etching process thereby to expose the aluminum surface of the bonding portion 80 to the outside.

The wafer thus covered with the final passivation film is died so that it is divided into separate pellets, which are then die-bonded to the tab lead on the lead frame.

Both the ends of the aluminum wire 10 are bonded to the bonding pad on the pellet and the outer connecting lead of the lead frame, respectively. That aluminum wire is made of an aluminum material having a diameter of 30 μm and containing 1% of silicon and 1% of copper. The material used for that aluminum wire has the same ionization tendency as that of the bonding portion 80, as has been described hereinbefore.

Thus, the local cell reaction, which is caused by the difference in the ionization tendency during a later-described second aluminum oxidization, can be prevented to form an aluminum oxide film having an excellent quality and a uniform thickness. The wire bonding step thus far described is conducted at the portion in which the bonding pad 28 has the stacked structure, as shown in Figure 2, i.e., above the contact hole 32. Moreover, the bonding step is desired to be conducted such that the bonded surface of the bonding wire covers the surface including the contact hole 32. Incidentally, the wire-bonded state will be clearly understood in view of Figures 1, 3F and 4.

Next, as shown in Figure 3F, a second aluminum oxidization is conducted to form the aluminum oxide layers 12, 13 and 14. First of all, the remarkably thin aluminum oxide films, which are naturally formed on the exposed surface of the bonding portion 80, the surface of the aluminum wire 10 and the aluminum vapor-deposited film 11 (which should be referred to Figure 1) on the lead outside of the Figure, are removed as a pretreatment of the aluminum oxidization. For this treatment, those surfaces are dipped in oxalic acid, for example, so that they may be etched. This pretreatment is effective for making dense the aluminum oxide film, which will be formed later, and for forming a film having a uniform thickness. Next, the second aluminum oxidization is conducted by leaving the lead frame, to which pellets are bonded, as a whole in the atmosphere at a temperature of 120°C and under a vapor pressure of 2 atms. The exposed surface of the bonding portion 80, the surface of the aluminum wire 10 and the aluminum vapor-deposited film 11 of the lead outside of the Figure are oxidized to form the aluminum oxide films 12, 13 and 14, respectively. These aluminum oxide films are made mainly of $A\ell_2O_3$. The aluminum oxide films 12, 13 and 14 act as protecting films to prevent the bonding portion

80, the aluminum wire 10 and the aluminum vapor-deposited film 11 on the lead outside of the Figure from corroding, respectively. Moreover, the aluminum oxide films 12, 13 and 14 are formed to merge into not only each other but also into the aluminum oxide film underlying the final passivation film which has already been formed by the first aluminum oxidization so that a high corrosion prevention effect can be enjoyed, as will be described hereinafter.

In accordance with another aspect of the present invention, all the leads are short-circuited by means of a short-circuiting portion 34, as shown in Figure 4, when that second aluminum oxidization is conducted.

The inventor has investigated the causes for the failure to efficiently form an aluminum oxide film having an excellent corrosion-resistance and a uniform thickness and has found that the causes are invited by the cell reaction which is established locally in the vicinity of the portion oxidized when the aluminum material has its surface oxidized to form the aluminum oxide film. According to the results of the investigations of the inventor, moreover, it has also been found that one of the causes for that local cell reaction results from the fact that the potential at the respective bonding pads and leads are made different by the potential differences at the PN junctions in the semiconductor substrate and by the contact potential differences at the portions connecting the semiconductor regions and the aluminum wiring layers. The algebraic sums of the potential differences at the PN junctions and the contact potential differences at the portions connecting the respective semiconductor regions and the aluminum wiring layers do appear as the relative potential differences of the respective bonding pads. Since the bonding conditions are common for all the leads, the potential differences of the bonding pads become, as they are, the relative potential differences between the respective leads. If the chip at that state is left in a wet atmosphere, the potential difference between the leads and the moisture in the atmosphere act to correspond to the contact potential difference between the two substances of a battery and a solvent, respectively, thereby to construct an equivalent local battery.

For example, if there is connected with a first bonding pad at a certain potential a second bonding pad having a higher potential than the former potential, according to the experiments conducted by the inventor, the forming rate of the aluminum oxide film on the aforementioned first pad is higher than that of the aluminum oxide film on the second pad so that a thick aluminum oxide film is formed. This is caused by the fact that the electrons generated in the course of that oxidizing reaction are attracted to the relatively higher potential side (i.e., the second pad side). In other words, the electrons generated at the first pad are attracted to the side of the second pad. As a result, the first pad proceeds in its aluminum ionization, because the electrons are held outside of the system of the oxidizing reaction, so that it becomes liable to be oxidized. On the contrary, the second pad is suppressed from having its aluminum ionization by the excessive electrons so that it becomes reluctant to be oxidised.

In the present method, however, all the leads 4 are electrically short-circuited by means of the short-circuiting portion 34. By having all the leads short-circuited, it is made possible to prevent the local cell reaction, which is invited by the potential difference between those leads, and to make the growing rates of all the aluminum oxide layers equal so that a film having a uniform thickness can be formed. Moreover, since the oxidizing reaction proceeds at a uniform rate all over the surface, it is possible to form an excellent oxide film having a uniform thickness. Still moreover, since the film thickness can be made uniform, as is different from the prior art, the disadvantage that another region has a larger film thickness than that required so as to attain a necessary thickness is obviated so that the aluminum oxidization can be efficiently effected.

Next, the whole structure is molded in the resin 31, and the short-circuiting portion 34 is subsequently cut off to form the leads 4 into a desired shape.

Next, as shown in Figure 5, the resin-molded semiconductor device is dipped in a solution of sulfuric acid (H_2SO_4), for example, to remove the oxide film from the surfaces of the leads 4. More specifically, the undesired oxide film, which is formed on the surfaces of the leads of 42 alloy (or bronze copper) because the leads have been held in a moisture atmosphere for the aluminum oxidization, is exclusively and locally removed by making use the difference between the properties of the aluminum oxide film and the undesired oxide film. For this purpose, the solution of sulfuric acid is used, because it does not act upon the aluminum oxide film but is operative to etch only the oxide film on the leads 4. This oxide film is removed by dipping the leads 4 in that solution for about five minutes. Even if, at this time, the solution of sulfuric acid penetrates into the resin, the aluminum-vapor-deposited film, the aluminum wire and the bonding pad are protected by the aluminum oxide layer so that they are not influenced in the least.

Thus, the oxide film, which has been formed on the surfaces of the leads during the aluminum oxidization can be removed after the molding step with the resin, by making use of the difference in property from the aluminum oxide film. As a result, at least that oxide film on the surfaces of the leads, which is exposed to the outside, can be completely removed to expose the clean surfaces of the leads to the outside. As a result, the electric connections can be maintained at such an excellent level as to enhance the reliability of the IC. On the other hand, if solder layers are to be formed on the lead surfaces, the soldering operation can be conducted to a satisfactory extent without elaborately subjecting the leads to the surface treatment for the soldering operation.

The present invention should not be limited to the embodiment thus far described. For example, before the chip is molded in a resin, it may be undercoated with a soft under-coat resin such as an RTV-11 resin. Then, it is possible to prevent the aluminum wires from being broken by the mold stress and the resin

and the aluminum wires from being separated to allow the moisture to reach the pellets. It is also possible to improve the humidity resistance.

Furthermore, the present invention can be applied to packages other than the resin mold type such as a ceramic type or glass type package so that the cost can be reduced with a high reliability while enjoying the features of the respective packages.

CLAIMS

1. A semiconductor device comprising:

a semiconductor substrate having a bonding pad disposed on an insulating film and made of an aluminum material containing a metal additive having an ionization tendency;

a lead disposed in the vicinity of said semiconductor substrate;

a bonding wire made of an aluminum material and having one end connected with said bonding pad and the other end connected with said lead, the aluminum material of said bonding wire containing the same additive as the aluminum material of said bonding wire; and

an aluminum oxide film formed on both the surface of said bonding wire and that surface of said bonding pad which is exposed outwardly of the portion thereof which is connected with said bonding wire.

2. A semiconductor device according to Claim 1, wherein the metal additive of said bonding pad is a copper material.

3. A method of fabricating a semiconductor device, comprising:

the step of preparing both a semiconductor substrate including a plurality of bonding pads formed on an insulating film and made of aluminum material, and a plurality of leads disposed to terminate in the vicinity of said semiconductor substrate and to correspond to said bonding pads;

the step of connecting said bonding pads and the corresponding leads, respectively, by means of wires made of aluminum materials; and

the step of forming films of aluminum oxide upon the surfaces of said bonding wires and said bonding pads by oxidizing said surfaces with said plurality of leads being electrically connected so that said leads may be maintained at an equal potential.

4. A semiconductor device fabricating method according to Claim 3, further comprising:

the step of molding said semiconductor substrate and a portion of said leads in a resin; and

the step of removing the oxide films from the surfaces of said leads.

5. A semiconductor device comprising:

a first conducting layer formed on a first insulating film over a semiconductor substrate;

a second insulating film formed on said first conducting layer having a contact hole exposing a portion of said first conducting layer to the outside;

a second conducting layer made of aluminum and formed on said second insulating film and to cover that portion of said first conducting layer which is exposed through said contact hole to the outside;

a bonding wire so connected with said second conducting layer as to cover said contact hole; and

a film made of an aluminum oxide and formed on the surface portion of said second conducting layer, other than the surface portion thereof with which said bonding wire is connected.

6. A semiconductor device according to Claim 5, wherein said bonding wire is made of aluminum and has an aluminum oxide formed on its surface.

7. A semiconductor device according to Claim 5 or 6, wherein said first conducting layer is made of aluminum.

8. A method of fabricating a semiconductor device, comprising:

the step of forming a first conducting layer on a first insulating film over a semiconductor substrate;

the step of forming on said first conducting layer a second insulating film which has a contact hole for exposing a portion of said first conducting layer to the outside;

the step of forming a second conducting layer in said contact hole and on said second insulating film;

the step of so connecting a bonding wire with said second conducting layer as to cover said contact hole; and

the step of forming a film of an aluminum oxide on the surface portion of said second conducting layer other than the surface portion thereof, which which said bonding wire is connected.

9. A semiconductor device fabricating method according to Claim 8, wherein said bonding wire is made of aluminum and a film of an aluminum ox de is formed on its surface simultaneously with the step of forming the aluminum oxide film on said second conducting layer.

10. A semiconductor device comprising:

an aluminum layer formed on a first insulating film over a semiconductor substrate;

a film of an aluminum oxide formed on the surface of said aluminum layer;

a second insulating film formed on said aluminum oxide film;

a hole so formed in said aluminum oxide film and in said second insulating film as to expose a portion of said aluminum layer, which forms a bonding pad, to the outside;

a bonding wire having a connected portion connected with said aluminum layer which is exposed through said hole; and

an aluminum oxide film formed on that surface portion of said aluminum layer, which is exposed through said hole around the connected portion of said bonding wire,

11. A semiconductor device according to Claim 10, wherein said bonding wire is made of aluminum and has an aluminum oxide film formed on its surface.

12. A method of fabricating a seminconductor device, comprising:

the step of forming a wiring layer and a bonding pad, which are made of aluminum, on a first insulating film over a semiconductor substrate;

the step of forming an aluminum oxide film over the surfaces of said wiring layer and said bonding pad;

the step of forming a second insulating film on

said aluminum oxide film, covering the semiconductor substrate;

the step of so locally removing said aluminum oxide film and said second insulating film as to expose a portion of the surface of said bonding pad to the outside;

the step of bonding a wire to an exposed area of said bonding pad; and

the step of forming an aluminum oxide film on the surface portion of the exposed area of said bonding pad other than the surface portion to which said wire is bonded.

13. A semiconductor device fabricating method according to Claim 12, wherein said bonding wire is made of aluminum and has an aluminum oxide film formed on its surface simultaneously with the step of forming the aluminum oxide film on the surface portion of the exposed area of said bonding pad other than the surface portion to which said bonding wire is bonded.

14. A semiconductor device according to any one of claims 1, 2, 5, 6, 7, 10, and 11, wherein said semiconductor substrate and bonding wire are molded in resin material.

15. A semiconductor device substantially as described herein with reference to the accompanying drawings.

16. A method of fabricating a semiconductor device, substantially as described herein with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1983.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

2105197

FIG. 1

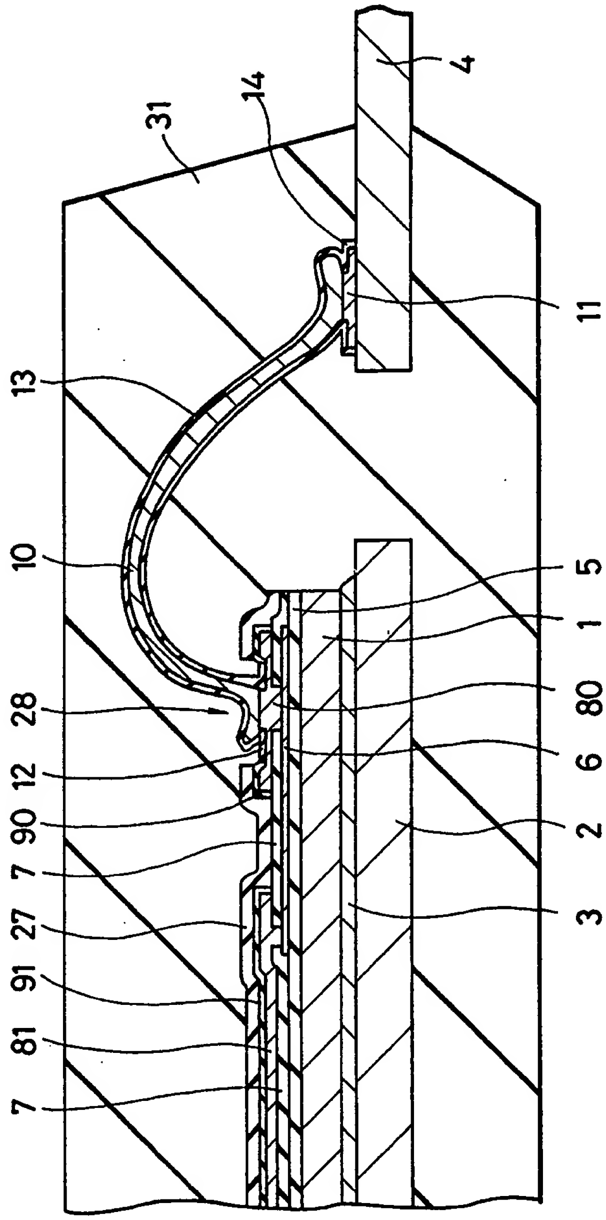
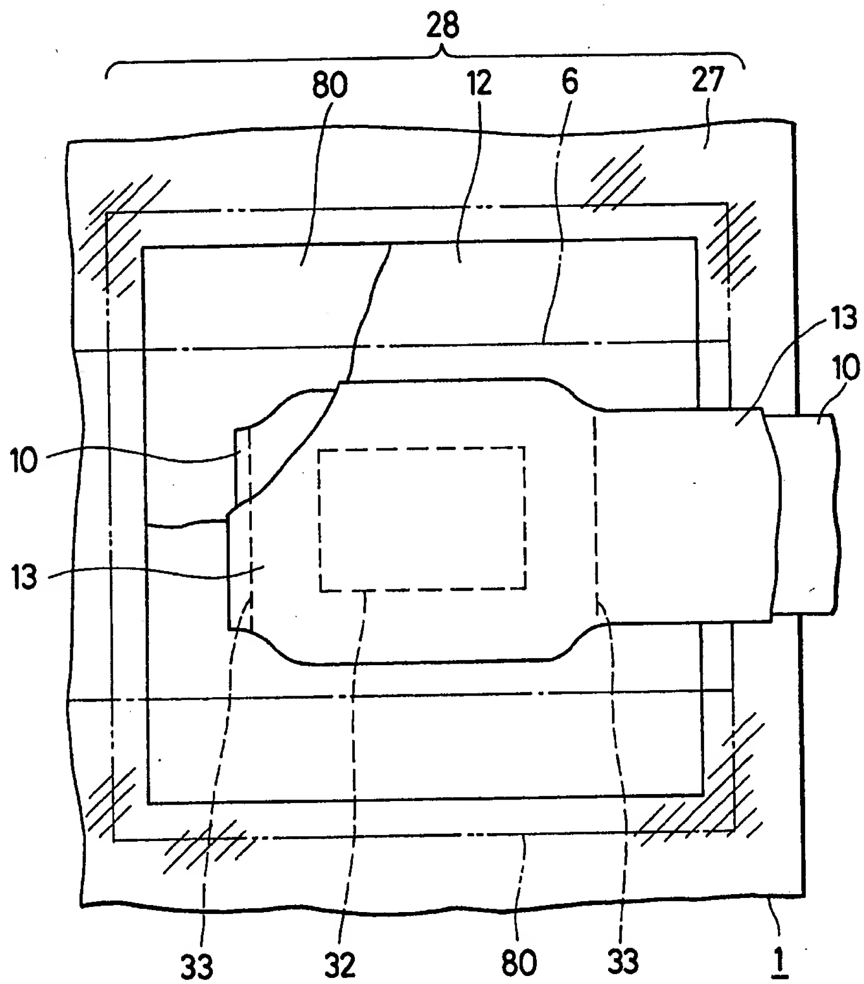


FIG. 2



2105107

FIG. 3A

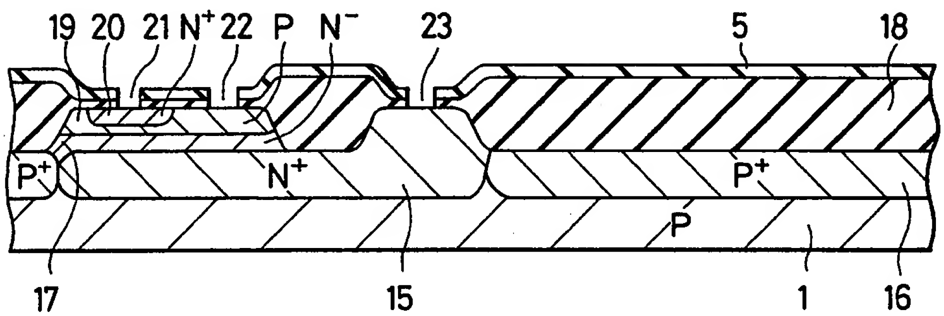


FIG. 3B

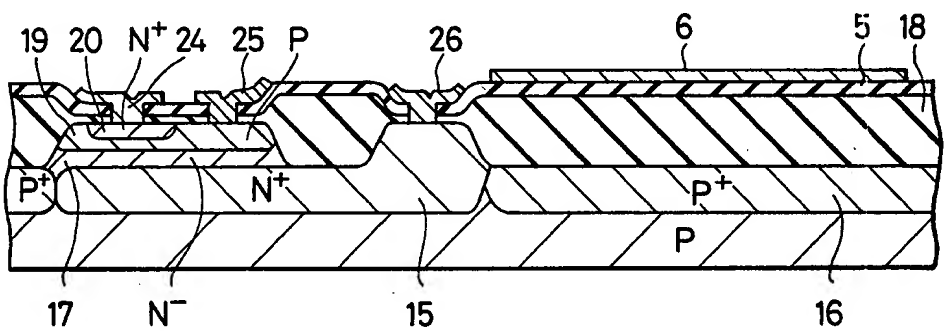


FIG. 3C

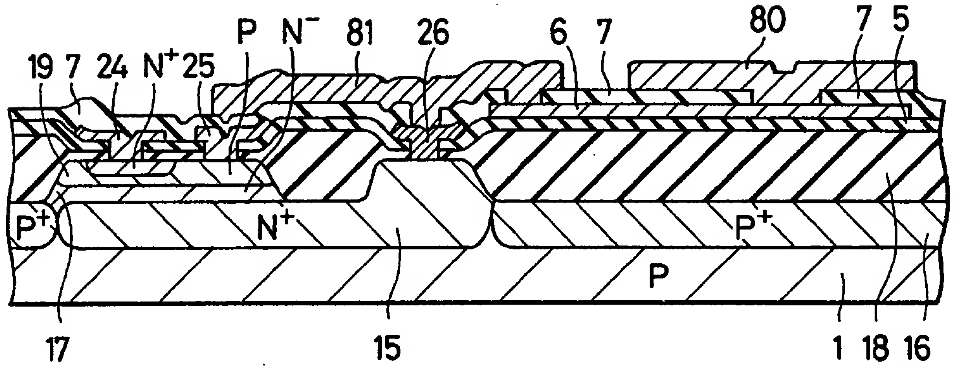

19 7 24 N+ 25
P N- 81 26
6 7 80 7 5
P+ N+ P+ P
17 15 1 18 16

FIG. 3D

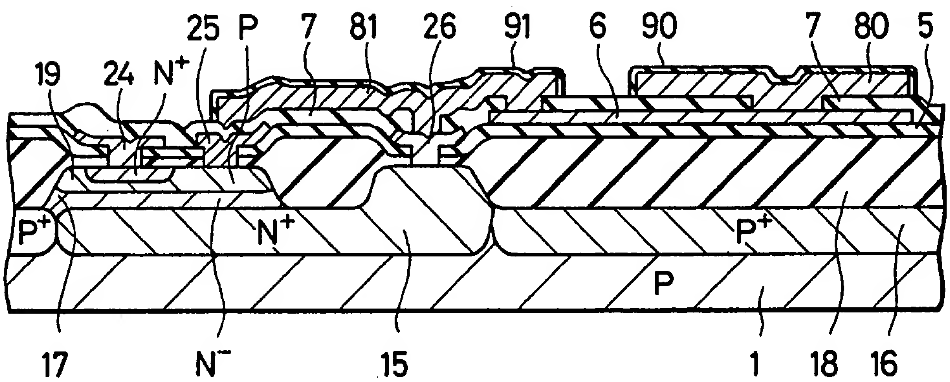

19 24 N+
25 P 7 81 26 91 6 90 7 80 5
P+ N+ P+ P
17 N- 15 1 18 16

FIG. 3E

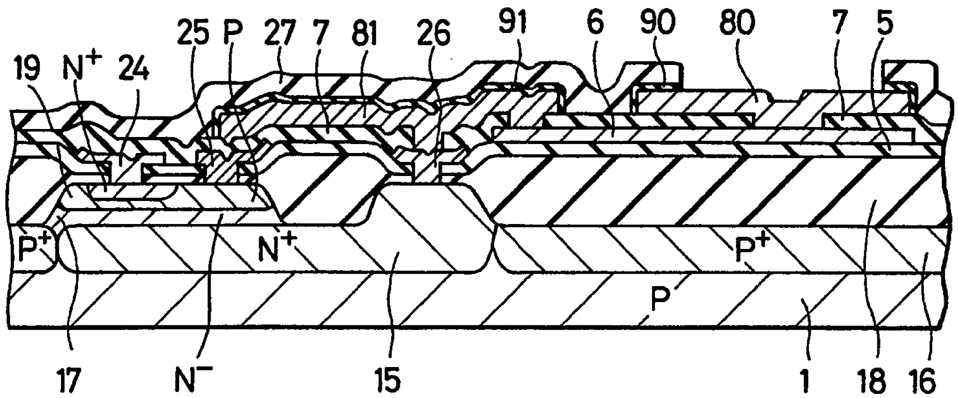
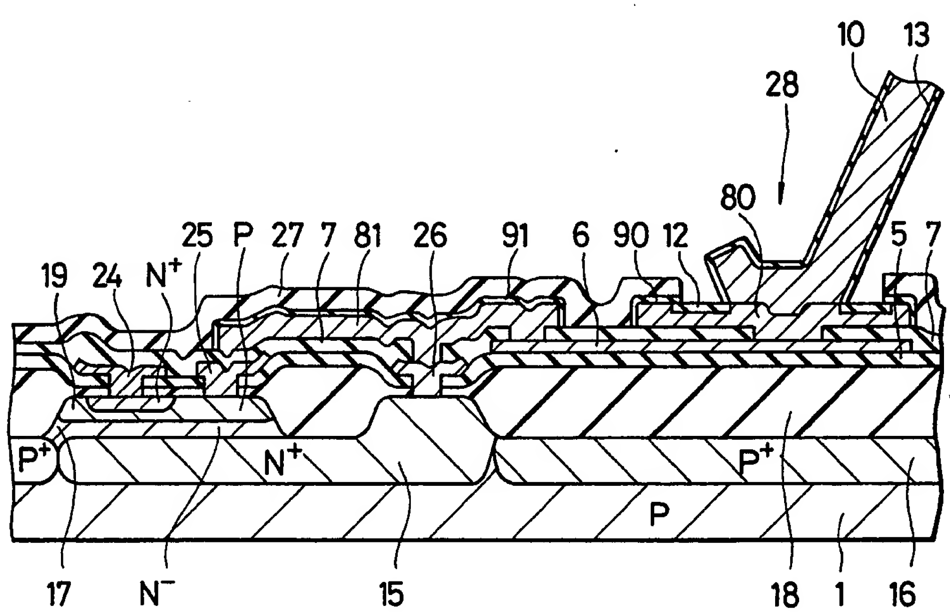

19
N+
24
25
P
27
7
81
26
91
6
90
80
7
5
P+
N+
P+
P
17
N−
15
1
18
16

FIG. 3F


10
13
28
80
19
24
N+
25
P
27
7
81
26
91
6
90
12
5
7
P+
N+
P+
P
17
N−
15
18
1
16

2105107

FIG. 4

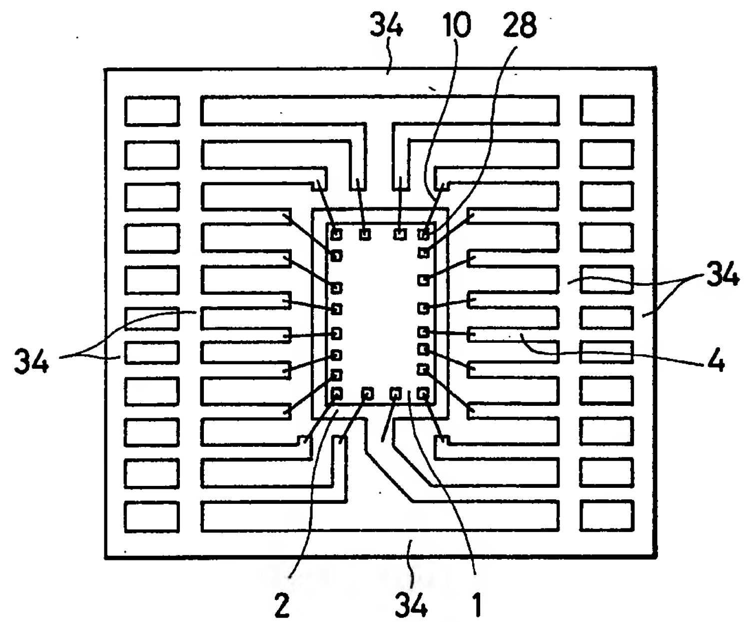


FIG. 5